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TITLE

OBSERVATIONS ON THE BIOLOGY OF DENDROCTONUS VALENS LECONTE BLACKS MOUNTAIN EXPERIMENTAL FOREST, SEASON OF 1941

By
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Berkeley, California
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RECORD FOR FILES OF OBSERVATIONS ON DENDROCTONUS VALENS LEC.
AT BLACK'S MOUNTAIN EXPERIMENTAL FOREST
AUGUST 22-24,1942

Biological Observations

During the season of 1941 a systematic study of some phases of the biology of Dendroctonus valens Leconte was made at Black 's Mountain Experiment Station. The results of this study have been reported (1). One of the objectives of the study was the determination of the sequence of broods and number of generations per year. From the observations made in 1941 it seemed that

(1) some host material could produce a full generation in a summer season

(2) stumps attacked early in the summer would yield one generation in a year, the larvae overwintering in prepupal state and transforming to adults the following spring one year after attack

(3) subsequent attacks on roots of the same stumps and on other stumps cut later in the season might yield adults over a period of more than one year, the broods requiring more than a year to complete development.

On August 22 and 24, 1942, inspection was made of two groups of stumps. The stumps of the first group were from trees cut in early June, 1941. Examination of this host material above ground and below ground including roots showed the early spring broods to have matured and escaped as adults, completing a generation in one year as expected. On one root exposed to a distance of 12 feet from a stump callow new adults were found in numbers at a distance of 8 feet. These adults appeared to have matured from broods established on the root by attacks which took place later in the season of 1941 after the stump had become infested above ground. The maturation of these broods in 1942 makes a one-year life cycle for these subterranean generations. It may be doubted, however, that these new adults will escape and reattack before the onset of winter. Instead, they probably will overwinter as adults beneath the soil and emerge from the roots in 1943 to make attack. Under these circumstances a period of about 22 months will have elapsed between the establishment of the original attacks and the attack of the new adults.

The second group of stumps that were examined were cut in the last week of July and first week of August, 1941. The stumps were infested during August, 1941, and to a small extent in 1942, as evidenced by recent attacks and very small larvae found during the present examination. In August, 1942,

the broods established by the attacks of the previous year were not quite full grown, the larvae varying in size from three-quarters to almost fully grown. A few larvae were found in the phloem above ground. Most broods, however, had mined below ground and out short distances along roots. On roots of one stump broods had reached distances varying from two to four feet along roots. These broods will not mature in 1942. They probably will overwinter as nearly grown, or fully grown prepupal larvae, transforming to adults in 1943. The life cycle of these broods will have been 22 months in length.

No observations were made on other stumps attacked late in August. It may be expected, however, that the larvae will not be fully grown at this time, and may not complete development and emergence until August 1943 or the spring of 1944.

From the observations made in the two years the life-cycle has been found to range between about four months to about twenty-two months, with the possibility of longer periods being indicated. It is evident that Dendroctonus valens is highly plastic in the degree to which its developmental rate may vary. This great range in length of life cycle probably accounts for the continual appearance and presence of new adults during the summer season.

Observations of Dendroctonus valens Activity on Cut Over Areas

In addition to the observations on the development of broods in host materials infested in 1941, a recruise was made of cut-over plots used in a study of the behavior of Dendroctonus valens on areas treated by sanitation-salvage methods. The results of this three-year study have been reported also (2). No new activity of D. valens on these areas in the current season was noted. Attacks made in the previous year on green trees standing near logs or which had been injured by logging activities have been unsuccessful. It is believed that the maximum danger of attack by valens to reserve trees in cut-over areas existed in the season of cutting, or while there was an abundance of fresh attractive host material present. Unless the valens populations are particularly high and aggressive, it would seem necessary to consider only those areas which have been cut within the season or which have carried fresh host material over winter from cuttings made late in the previous year when planning the application of measures to control attacks of valens on reserve trees.

The observations on Dendroctonus valens on August 22 and 24 are the only attention that has been given to the species in 1942. No further study of its biology is planned for the remainder of the year.

Black's Mountain Experiment Station
c/o Forest Service
Susanville, California.

August 24, 1942.

Respectfully submitted:

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Citations

1. Johnson, John W. "Observations on the Biology of Dendroctonus valens Leconte, Black's Mountain Experimental Forest, Season of 1941", Report for files, Berkeley Station, August, 1942.

2. Johnson, John W. "Causes and Effects of Dendroctonus valens Attacks on Reserve Trees in Areas Treated by Sanitation-Salvage Methods in Providing Trees more Susceptible to Primary Bark Beetles", Report for files, Berkeley Station, July, 1942.

Forest Insect Laboratory
Berkeley, California
September 7, 1942

OBSERVATIONS ON THE BIOLOGY OF DENDROCTONUS VALENS LECONTE

BLACK'S MOUNTAIN EXPERIMENTAL FOREST, SEASON OF 1941

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OBSERVATIONS ON THE BIOLOGY OF DENDROCTONUS VALENS LECONTE BLACK'S MOUNTAIN EXPERIMENTAL FOREST, SEASON OF 1941

'During 1939 a study was undertaken on the Black's Mountain Experimental Forest to determine the role played by the red turpentine beetle, Dendroctonus valens Leconte, in providing green trees on cut-over areas more susceptible to attack by other bark beetles. In the course of the study in 1939 and 1940 the need for a better knowledge of the life history of the species became evident as difficulties were encountered in coordinating field work with the activities of the insect. Because of this, and also because of a lack of any complete study of the biology of the insect in "east side" pine areas, work during 1941 was planned for systematic and periodic observations on the activities of the beetles and broods during the season. Completion of the study would contribute to a knowledge of the biology and life history of the insect under the virgin and cut-over stand conditions in northeastern California and form the basis for a paper adding new biological information to the literature of the species.

Because of the limited time available during 1941 for field observations and because of a lack or priority for continuing the study during 1942, it has not been possible to complete the investigations as planned. This report presents a detail of the observations made during 1941 and completes the study for the 1941 season.

Scope and Objective

The scope of the study of the D. valens biology was restricted to certain phases which could be followed within the time available for the work. Attention was given primarily to those objectives which fitted with those of the previous and separate study of the role of D. valens on cut-over areas in disposing trees to attacks by other insects. In studying the biology of the species the immediate objectives were to determine:

(1) the number of generations during the season and year

(2) the sequence of stages of the life history during the year

(3) the periods of dispersal of adults and of new attacks

In the course of the investigation of these points, specimens of the several stages of the life cycle were collected and preserved in alcohol and notes recorded to provide material for the more detailed study of the biology to be undertaken later. However, since no further work on the biology is anticipated immediately, some of these notes are incorporated in this report, making these records readily available for purposes of further reference.

Sources of Observations

Three types of host material were used for purposes of observation during the season, (1) green stumps left in the course of logging operations, (2) green logs, and (3) standing trees. Of these, the stumps were the chief source of information since they were most readily available and proved to be the preferred host of the beetles. Several series of stumps were used. The first consisted of stumps left by logging in the previous autumn of 1940 on a twenty-acre plot. The stumps on this plot contained parent adults only at the beginning of the summer, the adults

having overwintered from the previous season in short galleries beneath the bark. A second series was followed on an area where cutting had taken place during the first two weeks of June. Other series on plots and compartments cut in the course of the season were followed during the summer for a more complete record of the attacks of adults and of the development of broods during the season. Some additional information was obtained from records of attacks taken on green stumps on special study plots. Observations were begun on June 2, 1941, and continued at intervals of one or two weeks until the end of the season on November 3, 1941.

RESULTS OF THE STUDY

Number of Generations per Season and per Year

Number of generations in stumps:

In the stumps there was an incomplete generation during the 1941 summer season (Refer to Table 1). As a result, there will be but one full generation for the calendar year from June 1941, to June, 1942. Establishment of broods of the new generation began during early summer with attacks by overwintering adults, and by emerging new adults transforming from overwintering prepupal larvae. By November 3 larvae from these early broods had reached the prepupal condition, and after overwintering in this stage will complete their development in the spring of 1942. Younger broods in stumps attacked later in the summer entered the winter as eggs and small larvae. These may not mature until the end of the 1942 summer season, or perhaps until the spring of 1943.

Number of generations in standing trees:

In standing trees development may have been more rapid. One definite

Table 1. Occurrence of Life Stages in Stumps and Trees - Summer of 1941

Host	Life Stage	June 2	June 12	June 26	July 15	July 22	July 29	August 5	August 12	August 18	August 26	Sept. 2-5	Sept. 16	Oct. 8	Oct. 27-28	Nov. 3
Stumps and Trees	New Attacks	x	x	x	x	x	x	x	x	x	x	x	x			
	Parent Adults	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Eggs		x	x	x	x	x	x	x	x	x	x	x	x	x	x
	Larvae				0-¼	0-½	0-½	0-½	0-1	0-1	0-1	0-1	0-1	0-1	0-1	0-1
	Prepupal Larvae											x	x	x	x	x
Trees Only	Pupae											x		x		
	New Adults											x	x	x	x	x

record was obtained of a full generation developing in the summer season in a standing green stub resulting from tree breakage during logging operations in June. This stub was subsequently attacked and broods successfully established. On October 8, prepupal larvae, pupae, and callow adults were found. Since these new adults probably remained in the tree over the winter, there will be but one full generation for the year. In the case of two other standing trees, it appeared that a full generation may have developed during the summer followed by emergence of new adults, and perhaps establishment of a second partial generation. One of these trees contained fully colored new adults in September. The brood was largely abandoned in the other. There was some uncertainty, however, of the date when these broods were established, thus making the records inconclusive.

Comparison with reports of other observers:

The indicated single generation per year is somewhat less than reported for the species in another part of California. In a study of the species on the west slope of the Sierras, Struble (13) indicates that a full generation and a partial second may be expected. Walther (15) suggests that two generations per year probably develop in the vicinity of San Francisco. Other reports indicate that the life cycle is quite variable in different parts of the natural range of the species (7, 8, 10). There is the possibility that at Black's Mountain the development rate may vary from year to year, depending on conditions during the growing season.

Sequence of Life Stages During the Year

The occurrence of the several life stages of the new generation during the 1941 season is summarized in Table 1. Starting with the presence of

overwintering adults in the spring, there is an accumulation of eggs, larvae of all sizes, and finally pupae and new adults as the season progresses. Observations showed that larvae of various sizes were present in trees attacked the previous year. These broods continued to mature and the adults to emerge during the summer months. As a result, all stages of the life cycle were continuously present in the forest throughout the season.

New attacks: and parent adults:

New attacks were present from June to the middle of September. Parent adults were present in all months. A large percentage of the D. valens population appeared to overwinter as parent adults in new short galleries, in partially completed or old galleries, and as new adults in the old broods spaces beneath the bark. The adult stage appears to be a usual overwintering condition. Observations on green overwintering stumps at the beginning of spring showed the presence of many adults in short spaces or galleries in the phloem in which the winter had been passed. Again in the autumn of 1941 after the first winter snows, parent adults in numbers and new adults were present beneath the bark of stumps and trees.

Eggs:

Eggs of the new generation were first observed on June 12, 1941. Thereafter they were present in some galleries throughout the season, some still being present at the onset of winter. It is possible that the eggs may be able to survive winters and serve to some extent as a means of passing the unfavorable season.

Larvae:

Larvae of the new generation were first observed after July 15. With the continuous establishment of new broods during the summer larvae of all sizes were found. In early summer while the larvae of the first 1941

broods were yet small, larvae of later instars were present in hosts attacked the previous season. By the end of the summer broods which had been established in early June had reached the prepupal condition. In stumps development was arrested at this point, the broods passing the winter as prepupae in pupal cells. In standing trees some larvae continued to develop into pupae and to adults. Even in these trees, however, a few larvae remained in the prepupal state. The prepupae, as the adults also, would appear to be favored as a stage for passing the winter. However, many smaller larvae entered the winter season also. Such small larvae may carry through successfully.

Pupae and new adults:

The occurrence of pupae and of new adults of the 1941 generation was first observed in September. Pupae were few at this time. Some pupae may have entered the winter. This stage would not seem to be of common occurrence in overwintering broods. Larvae reaching the prepupal condition at the beginning of autumn tended to remain in this stage. The pupae formed in late summer completed their development for the most part to new adults before the onset of cold weather. These adults either overwintered in the pupal cells or emerged to initiate new attacks in which hibernation occurred. Lighly colored, apparently new adults were encountered throughout the season about new stumps, in flight, and sometimes perched on the walls of buildings. These adults were believed to have had their source in the overwintered broods of larvae of the previous year. Their continued appearance during the summer months indicated the presence of pupae, also, throughout the growth season

Periods of Dispersal and of New Attacks

Occurrence of periods in the season:

Soon after the first of June in periods of warm weather, D. valens adults became active and were widely dispersed over the area. New attacks mounted rapidly on stumps left by logging operations during the first weeks of June. In this month adult activity was at its greatest for the season. After the first of July the rate of attack fell off decidedly and never again approached the level of the first weeks in the spring. Stumps from cuttings in late June and early July failed to fill up well with attacks during the remainder of the summer.

In the month of August there appeared to be a renewal of adult emergence, dispersal, and reattack. Counts of attacks on stumps cut in August, however, showed that the infestation was only one-third as heavy as on areas cut in June. The second period of adult activity possibly continued into the first two weeks of September. On September 13 a swarm of D. valens adults was reported to have appeared at Butte Lake, Lassen National Park, California, twelve miles distant from the area in which the studies were made. Stumps cut during September at the experimental forest remained almost wholly unattacked, indicating the end of the 1941 season of adult activity.

Sources of adults:

During the first and major flight period the source of the adults is believed to have been the overwintering adult population and the maturing overwintering prepupal broods. The source of the adults for the second flight would seem to have been the maturing broods which had overwintered as small larvae, and perhaps to some extent maturing broods of the 1941

summer generation in standing trees. Between flight periods some adults were always moving through the area establishing attacks on new host material. This continuous occurrence of attacks by D. valens is believed due in part to the repeated emergence, reattack, and establishment of successive broods by individual adults and in part to a gradual completion of development of broods of the previous year.

Course of infestations in stumps:

Repeated examination of the attacks and development of Dendroctonus valens in stumps indicated that the behavior of the beetles followed a general pattern. There was a similarity in the sequence of attack, brood establishment, and brood development in all series of stumps examined during the summer.

The attacks: attack and brood establishment began first in the parts of the stump at and above ground level. Some attacks were established just at soil level and on portions of the roots at the ground surface. The period of attack embraced a shorter or longer interval of time depending on the time of the year. Stumps were attacked more rapidly during the spring flight period and the warmer part of the summer. Stumps from trees cut in late summer or in autumn may again be attacked in 1942. During the early summer, attacks took place over a period of about six weeks. At the end of this interval most stumps were completely filled. However, an occasional new gallery was found in unoccupied patches of phloem even two months after the first attacks took place.

By far the greatest number of attacks occurred within the first two or three weeks after the trees were felled. (Table 2) Stumps would appear to be most attractive during this time. On two study plots 62 percent and

73 percent of the total number of attacks occurred within three weeks of the time when the trees were cut. Stumps from trees cut during periods of low D. valens activity drew only a few beetles in the next flight period. Instead, attacks were concentrated on the new fresh material of more recently cut areas.

Table 2. Occurrence of New Attacks of D. valens on Stumps in Cut-over Plots

Plot No.	No. Stumps	Date of Cutting	No. New Attacks at Intervals - Weeks One	Two	Four	Six	Eight	Total Att.	Av./Stump
Plot 1	15	June 5	154	432	124	140	100	950	63
Plot 2	21	Aug. 4	143	163	74		41	421	20

Adults: During and after the period of attack parent adults were present in numbers for several weeks in egg galleries in the parts of the stump above ground. There were usually two adults per gallery, averaging 1.95 adults in 101 cases for which records were kept. New and old galleries often had but one adult. At times three or four or more adults were found in a gallery. This may have been due to a coalescence of separate attacks since this is a common occurrence in well-infested stumps. Beetles were collected from egg galleries, but the sex ratio of these has not been determined yet.

Table 3. Grouping of Adults in Egg Galleries

	No. Adults per Gallery 1	2	3	4	5	6	Av./Gallery
No. Galleries	23	67	6	4	1	-	1.95

By the end of about six weeks parent adults began to disappear from the aerial parts of the stumps. An occasional adult was found under the bark for several months afterward, however. The fate of the beetles which left the parts of the stumps above ground was not certain. It is believed that part of them at least initiated new attacks on the same stumps below the ground surface. Others may have abandoned the stumps and sought new host materials to establish second broods.

Infestation of the stump below ground: As adults began to disappear from egg galleries in the stumps above ground, attacks began to develop in numbers on the butt of the stump below ground and on the upper ends of the roots. The initiation of attacks below ground was not merely an extension of existing galleries below soil level. This phenomenon occurred to some extent, but the majority of the attacks were distinct, and the egg galleries unconnected with those above ground. The transfer of activity from the aerial parts of the stumps to the subterranean took place in four separate series observed in the summer of 1941.

In the late summer series it occurred while some of the stump surfaces above ground were still unattacked. It is possible the infestation of the subterranean parts of the stumps is the usual habit of the adults after they have established broods above ground where they were first attracted.

Infestation of the roots progressed by a succession of attacks extending downward and outward from the butts of the stumps. In consequence the newest galleries and youngest broods were farthest from the root bases. After entrance into the roots, the beetles extended the galleries downward from points of entrance. After oviposition and completion of a gallery, in some cases the adults bored out through the bark and channeled downward

through the outer layers of bark and between the soil and bark for two or three inches. Entrance was again made into the root phloem and new galleries established. It appeared that individual adult pairs or single females probably established two or three or more successive broods during a season in this way. In the deeper galleries adults were not so regularly found in pairs. Single beetles were encountered frequently. The attacks extended down the roots various distances, being farthest from the root bases on the oldest stumps. The maximum distances along the roots reached by the beetles were between five and six feet and at depths in the soil of ten to twenty inches. By the end of the season adults began to disappear from the roots of the older stumps, indicating the limits to which such host material would be infested.

Larval development in stumps: The course of larval development and of their activities in stumps paralleled that of the parent adults. Larval broods, first established by the parent adults in the parts of the stumps above ground, developed for a time in the phloem adjacent to and surrounding the egg galleries. By six to seven weeks after the beginning of attacks, however, the larvae were between one-quarter and one-half grown. In well-infested stumps by this time most of the phloem above ground had been consumed. (Figure 4) The larvae then began to mine in groups toward the ground and into the phloem of the stump below the ground surface. This movement into the subterranean parts of the stump occurred with and followed the onset of adult infestations below ground. Below ground the larvae continued to mine out the phloem of the butt of the stump and to extend their feeding down along the roots on all surfaces. Before and during the migration the identities of family groups were lost, and larvae of younger broods mingled with those of older. Masses of larvae

of all sizes were a common occurrence. In most cases larvae from above ground did not appear to extend their feeding mines more than about three feet from the stump along the roots. By the end of the season, the larvae of the oldest broods were full grown and entered the winter as prepupae in pupal cells in the frass between the wood and bark along the roots. Larvae developing from eggs in root galleries extended their feeding spaces to distances more than five feet from the stump by the end of the season. At this time such larvae were not fully grown and may be expected to continue movement along the roots the following year.

From these records the course of events in the infestation of stumps would appear to follow this sequence:

1. a period of two or three weeks during which the stumps have maximum attractiveness for the beetles.

2. a period of about six weeks during which egg galleries are established above ground.

3. disappearance of the adults from the stump above ground coincident with the development of attacks on the stump and roots below ground.

4. migration of larvae from above ground to the stump below ground and to the roots.

5. establishment of new attacks along the roots.

6. adults abandon roots of stumps below ground, larvae from all broods continue their development. After transformation new adults emerge in the succeeding season or seasons.

Other Biological Observations

When periodic examinations were made to determine the general phases of activity of D. valens during the season, other biological notes were kept also. These would be of assistance in any further studies of the insect. For the purpose of providing a record of these notes, they are presented in this report.

Habits of Attack:

Entrance into the bark was made in bark crevices, beneath loose bark scales, beneath exfoliating sheets of bark, and at edges of wounds. Attacks were made on roots as well as on boles of standing trees, on roots and aerial parts of stumps, and on green logs. One standing green tree showed an attack on a root twenty-six inches below the trunk and eight inches beneath the soil surface. The adults had crawled down the root between soil and bark to make their attack. On the boles attacks occurred for the most part within one to three feet from the ground, but one attack eight feet up the trunk of a standing tree was observed. Attacks on logs were few, and tended to occur towards the butt ends of the first logs of trees. One exception was found, however, in which an overwintering log was moderately infested all along its under side.

Egg galleries:

Egg galleries in standing trees and in fresh stumps producing pitch, usually, but not always, were extended upward from the points of entrance. (Figure 1) On the roots of standing trees as well as of stumps the galleries generally extended downward from the points of attack. The length of the galleries varied from three or four inches to thirty inches in one case. Most galleries on trees and stumps were extended upward six to ten or twelve inches then curved over and extended downward. (Figures 2,3,4) Galleries were variously lobed and sometimes forked or branched. Often

Figure 1.

Characteristic new egg gallery on side of a stump. Gallery began at lower end. A pair of adults were at upper end in small space extending gallery upward parallel with wood grain. Remainder of gallery frass-filled. White egg mass barely visible along upper third of left side of gallery between frass and phloem. Note irregularities in width and direction of gallery.

Figure 2.

New looped egg gallery. Gallery began at right, ascended two inches, then looped over and descended with the grain. A pair of adults were at lower end.

Figure 3.

Extended feeding area of small larvae on side of stump. Larvae of several adjacent galleries have mined out a feeding space in phloem leaving dark colored frass accumulated in patches between bark and wood. Egg galleries packed with frass and abandoned by parent adults. Note the looping over of the galleries.

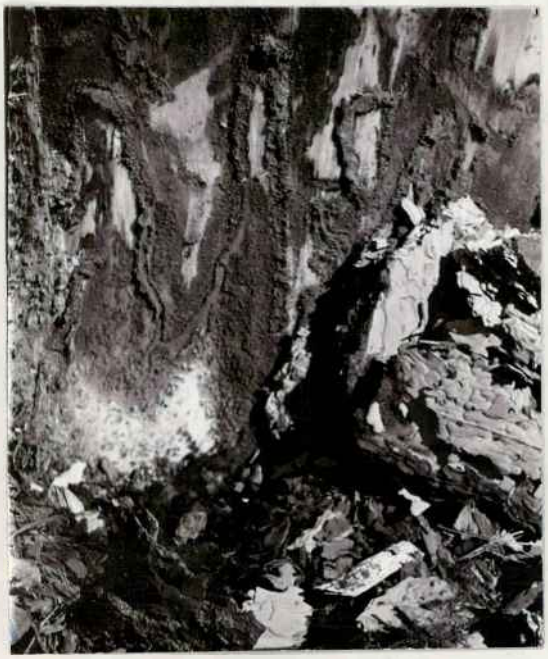

Figure 4.

Advanced infestation on side of a stump. Multiple looped frass-filled egg galleries are abandoned by adults. All eggs have hatched. Larvae have mined outward from galleries into phloem, leaving patches of white untouched tissue. Larvae about one-half grown, some barely visible at lower left center mining at edge of white phloem toward ground.

adjacent galleries coalesced. In roots galleries tended to be shorter, straighter, and less lobed. Galleries tended to follow the grain of the wood, and spiraled somewhat with spiralled grain. The galleries were largely packed with frass, but contained larger or smaller spaces free of frass in which the adults lived.

Pitch tubes usually were one to the gallery. In some cases, however, more than one tube was present at different levels on a gallery. In such circumstances there appeared to be more attacks than actually were present, and the older abandoned tube gave a false impression of unsuccessful attack. Pitch tubes were found beneath the soil on roots of standing trees, the pitch being forced out to the root surface against the soil by the beetles. Roots of fresh stumps gave off pitch, but those of older stumps did not.

Ventilation holes: The beetles bored numerous holes outward into the bark from the egg galleries as enlargement of the galleries progressed. Most of these "ventilation holes" (8) were at nearly right angles with the bark surface. Their diameter was slightly greater than that of the beetles, averaging about four mm., and varying from three to five mm. Their length was variable. In some cases they reached the bark surface, and boring dust and pitch was forced out through them. Many were constructed nearly to the surface, but were separated from the surface by less than the thickness of a bark scale. Others scarcely entered the bark. Occasionally a hole branched into two towards the surface. The holes in the vicinity of the space occupied by the adults usually were free of frass. Holes along older parts of the gallery usually were packed with frass, and very tightly. One case was found in which eggs were packed into the hole with the frass. New attacks in older stumps which produced little or no pitch gave an appearance similar to that of

the ventilation holes. This situation made counts of new attacks on stumps quite unreliable after the stumps were several weeks old. On roots ventilation holes were constructed abundantly, often reaching the bark surface. Boring dust was sometimes forced out to the surface of the root and against the soil. The ventilation holes generally were plugged with frass, with some exceptions where they communicated with chambers occupied by the beetles.

The development of attacks, and egg galleries on roots differed little from that on parts of trees and stumps above ground.

Adults:

The adults appear to have a long life. Evidence of establishment of successive galleries in roots pointed to a full season of activity, perhaps following a previous hibernation, thus giving a full year as a possible life span. Dead adults in older stumps were found towards the end of the summer, indicating that mortality of the beetles was taking place at the end of the season of activity. Adults appeared to have a long oviposition period, or perhaps a series of recurring ovulations making possible the establishment of successive broods. The adults were highly resistant to pitch. They were able to continue their activities while immersed in fresh liquid resin. Occasionally unsuccessful attacks were found in which the pitch flow seemed to have been fatal to the beetles.

The adult beetles have a well-developed capacity for stridulation. A clicking sound was emitted when they were handled, or when they were disturbed in their galleries. Sounds also are produced spontaneously when the beetles are undisturbed in their galleries. In one case, the sound was audible at a maximum distance of four feet from a stump in which attacks were in progress. The sound producing mechanism was not discovered.

(This is known as the stridulating process for sound in the male - EWC)

A dropping response is shown by the adults when they are disturbed while clinging to walls, screens, or sides of stumps. The beetles let go their hold and fall to the ground where they attempt to make off.

Swarming of adult D. valens was resported in September. Mr. John Rutter, Park Ranger, Lassen National Park, reported the appearance of a swarm of D. valens adults on September 13, 1941, at Butte Lake. Mr. Rutter's account follows:

"The flight occurred about mid-morning and appeared to be about two hundred feet high. It was a swirling type much like a swarm of bees. The first point was fairly compact and high with none of the beetles reaching the ground. My attention was called to the flight by a slight hum, and after several minutes numerous beetles were passing close to the ground and identification was possible. The main flight passed for about ten minutes with considerable stragglers passing for five minutes later. The mass did not move fast, but however, the direction seemed to be direct or positive, that is, it moved straight and direct. After this flight no unnatural amount of beetles was noticed, but prior to the flight and particularly the first day before, more D. valens were in the air than I have noticed at any time in this area. This amount did not constitute a flight but were just numerous and noticeable." (12)

This is the only report which has been found of true swarming of D. valens in California. There would seem to be no reason to doubt the observer's account of the beetle swarm, but the record is open to question since the specific identification of the beetles was not made by a specialist. That valens will swarm under some conditions is supported by Hopkins' reports (7, 8) of a vast swarming that took place on April 30, May 4, and other dates in 1893 in West Virginia. The beetles are stated to have

swarmed in clouds, the flight passing for miles over the countryside and crossing the Allegheny Mountains.

Eggs:

D. valens appeared to be highly fecund. Eggs were oviposited in large numbers and grouped together in one or more masses in the egg galleries. The numbers of eggs in the masses varied from two or three to more than one hundred. Galleries tended to have one large mass of eggs, and perhaps one or two smaller masses, these being separated by varying distances. In many galleries all eggs were in one group only. Rarely the eggs were found scattered through the frass which filled the egg gallery.

The egg masses usually were laid against the green phloem forming the side walls of the galleries. One case was observed of a small cluster of eggs oviposited in a ventilation tunnel in the bark. The masses were held in place by a layer of well-packed frass that appeared to be somewhat cemented together to form a coherent material. In form and length the masses varied much. Usually the eggs were oviposited in long strips several eggs in width and thickness. The length of the strips varied from two or three millimeters to more than four inches. Within the strips the eggs had no definite orientation.

Embryonic development of the eggs appeared to require a number of days. The first eggs of the 1941 generation were observed on June 12. Larvae were not found, however, until after June 26. Again, in vials of phloem in the laboratory two pairs of beetles oviposited on A ugust 31, 1941. Small first instar larvae were not observed until October 7, 1941. These records indicate an embryonic period of more than fourteen days to about five weeks. Hopkins (8) suggests that the embryonic period covers a week to ten days. The development of the eggs within single large egg

masses was not synchronous. While eggs at one end of a strip-like mass would appear to be recently laid, being white and homogeneous in color, there would be a progressive advancement in development along the strip; the eggs at the other end being cream-colored and showing the differentiating larvae within. In some cases newly hatched larvae were found at one end when at the same time the eggs at the other end still showed little embryonic differentiation. This variation in advancement of embryonic development from one end of an egg mass to the other would seem to indicate that oviposition took place over a period of many hours or several days.

Larvae:

After eclosion from the egg, the larvae attack the green phloem of the wall of the egg gallery against which the eggs were laid. The empty egg shells are not consumed. The larvae feed together in a mass extending a space out into the phloem away from the gallery. The feeding spaces are extended irregularly in any direction, leaving patches of unconsumed phloem (Figure 3,4). Masses of larvae from different galleries gradually work out all phloem and separate the bark from the wood.

The size of the larvae in the larval groups varied considerably where the larvae came from a large mass of eggs, a result of the variation in time of hatching. Generally, also, in well- infested stumps the separate larval masses of different galleries came in contact with each other, allowing further mixing of larvae of different sizes and ages. The larvae tended to keep together throughout their development, and in many cases pupated close together. In some instances, however, full grown larvae were observed mining singly or in twos and threes away from the main mass at the top of the feeding area in narrow phloem galleries several inches long. These ran at various angles, but generally straightened out and curved upward toward the vertical, being extended

upward. At the ends of such individual galleries pupal cells were constructed. At any time during their development smaller masses of larvae detached themselves from the main group and went their own way in the phloem.

As the phloem above ground was consumed, all larvae gradually migrated below ground. In stumps late in the season that were not fully infested, this same migration downward occurred while there was still phloem available in large amounts above ground. Below ground the migrating larvae extended their feeding out along the roots for two or three feet. Larvae from broods underground extended the feeding spaces along the roots out to five or six or more feet from the stump. In standing trees the phloem was mined out upwards for various distances, from six to eight feet or more in some cases. In the standing green twenty-five foot stub on Compartment P 15-33 which was attacked in the spring of 1941, the larvae appeared to have mined the phloem to the top.

Feeding of the small larvae is in the inner layers of the phloem. As the larvae increase in size, they attack the outer portions and later consume the whole thickness. After reaching about one-half size the larvae sometimes individually mine outward into the phloem, making pits and holes into it and extending channels within the phloem layer separate from the wood. Other larvae follow the first, enlarging the spaces and consuming the separating layers, thus gradually enlarging the general feeding space. Behind the masses of advancing larvae accumulates a rusty-red frass of very fine consistency and wet with resin. This is channeled by the movements of larvae, which concentrate it into patches. (Figure 3)

The larvae show remarkable tolerance to fresh liquid resin. In one standing tree, half-grown larvae were found successfully developing while bathed in a copious flow of fresh resin. In stumps, larvae usually were wet with resin which seemed to be without effect upon them.

Some evidence was found that the larvae suffer from a wilt disease. Two trees were found which contained dead fully grown larvae in various stages of decomposition. Some larvae appeared to be normal except for lack of powers of movement. Others were limp and somewhat dull in color. In later stages of deterioration the larvae were discolored, or dark brown, more flattened, and internally decomposed.

When the larvae reach full size, feeding stops and pupal cells are prepared. In most cases pupal cells are formed under the loosened bark, sometimes scattered or more often in groups in the old frass accumulations from larval feeding. The larvae make the cells by slightly hollowing out the inner bark, and pressing the frass into a ring encircling an oval space between bark and wood. Within the cells the larvae pass into the quiescent prepupal condition and later transform. In the bark of two standing trees a number of pupal cells were found within the bark itself well separated from the wood. The larvae had bored out into the bark before constructing the pupal chambers. Again in three trees full grown larvae were found separately mining galleries into the phloem at the edges of the feeding area. Some of these anastomosed to some extent and contained two or three larvae traveling end to end. At the ends of some of these galleries pupal cells appeared to have been formed.

Pupae:

Few observations were made on pupae. The length of the pupal stage may be quite short. One record of the transformation of a larva in the laboratory showed a pupal period of about eleven days. The pupae are very white when first formed. As development progresses, the eyes become pigmented and the pronotum and bases of the elytra faintly brown. Transformation to the adult occurs while the pupa is still lightly colored. During the pupal period the pupae respond to vibrations by twisting the abdomen vigorously. The heads of the pupae usually are at the higher ends of the cells.

New Adults:

Immediately after transformation the new adults are almost colorless and very feeble. The development of coloring and of the adult powers of movement and coordination of activities requires several days. At first the new adults rest quietly in their cells with the legs drawn up close against the sides of the bodies. When they are fully matured, they bore out of the pupal cells through the frass into the common space under the bark and escape. In one tree new adults were found grouped together. Some were boring outward through the bark, one taking the lead, and others following immediately behind.

Natural Enemies:

Natural enemies of Dendroctonus valens appeared to be few. Beneath the bark in the feeding spaces of the older larvae Temnochila virescens chlorodia (Mann.) adults and larvae were found occasionally. None were found in fresh egg galleries or in feeding spaces of young larvae. In the vicinity of prepupal larvae, pupae, and of new adults, adult Temnochila were found also. No cases of actual feeding of the predators on life stages of D. valens were seen. Clerids were never observed in or about D. valens infestations.

Woodpeckers appeared to be most effective enemies of the full grown larvae under the bark of standing trees. The birds located accurately the position of groups of large larvae beneath the bark and opened spaces to the wood surface sometimes several inches square in order to remove the larvae. Many large broods in standing trees were completely destroyed by the thoroughness of the birds. Woodpeckers also attacked and cleaned out many small infestations of D. valens about the bases of tree stems, perforating the bark over the attacked areas with round holes one-half inch or more in diamter and removing all stages of the insects.

Co-inhabitants of D. valens galleries:

Throughout much of the growth season egg galleries and larval feeding spaces contained other organisms in addition to D. valens life stages. Most abundant in the moist frass of the egg galleries on stumps were small delicate white mites. In addition to the mites nematode worms were numerous, at first as slender, smaller worms in the frass of the egg galleries, and later as larger individuals in the feeding spaces of the larvae. It appeared that the nematodes migrated from the galleries into the feeding spaces as these were extended. In the feeding spaces many worms were present during mid-summer. The worms tended to group themselves in the moist frass close behind the feeding D. valens larvae, but did not mix with the larvae to any extent. No nematodes were observed in root egg galleries or in feeding spaces of broods separately established on the roots. Towards the end of the season the nematodes disappeared from the valens infestations.

Small histerids were a third organism found occasionally in feeding spaces of the larger larvae. The nature of their activities was not apparent.

Blue Stain occurrence:

Blue stain was found irregularly beneath galleries or larval feeding spaces. There was no consistent occurrence of the stain with either the galleries or the feeding spaces. It was not observed in the wood beneath fresh or recent attacks or beneath recent larval feeding spaces. None was observed underneath valens wounds in living tissues of standing trees. Its occurrence suggested that the beetles may introduce the spores incidentally into their galleries, or that the loosening of the bark and opening of the bark by the D. valens infestations may be the chief means for its entrance into the wood.

Occurrence of D. valens in standing trees:

Observations were made on the attacks of D. valens in fourteen standing trees during the season. Five were low risk trees on areas treated by sanitation-salvage methods. Three were high risk trees on a study plot. The remaining six were scattered through the other forest compartments. Evidence from these several cases would seem to indicate that D. valens under proper conditions will attack and develop broods successfully in both low and high risk trees. On a cut area, one low risk tree adjacent to a stump suffered fourteen attacks, some of which showed larval broods half-grown at the time of examination.

In the season of 1941, three trees were observed in which D. valens had effectively girdled the stems. A fourth was found in which extensive new attacks appeared likely to result in girdling of the tree also.

Three of the trees were felled to determine the character of the insect infestations in the upper boles. In all three, it was found that Melanophila attacks had preceded D. valens attacks. In two of the trees, however, valens appeared to have become successful before the Melanophila broods. In the third tree D. valens appeared to have developed after the successful development of flatheaded borer broods. In addition to the Melanophila attacks, D. brevicomis infestations were present in two trees, and D. monticola had attacked one tree. The D. brevicomis attacks were subsequent to those of D. valens. In these four cases D. valens attacked trees previously suffering attacks from other insects or which had suffered mechanical injury. By its girdling activities the species insured the death of the trees.

Possibilities for rearing valens in the laboratory:

D. valens would appear to offer good possibilities for artificial rearing. New adults, when placed in vials, fed readily on phloem when

it was introduced into the containers. It was possible to maintain the beetles alive for more than a month in this way. Pairs of parent adults when taken from egg galleries and placed in vials packed with phloem, constructed galleries and oviposited in the vials. The eggs subsequently hatched and the larvae reared for five days before they were preserved in alcohol. The parent adults lived for five weeks before they were killed. Nearly fully grown larvae also were brought into the laboratory and maintained in vials of phloem. From these larvae several new adults were reared. All vials of living stages were kept in a moist chamber to prevent the phloem from drying out too rapidly. From these trials it would seem that D. valens might be reared readily in the laboratory from generation to generation, making possible a determination of the more intimate phases of its life history which thus far have remained unstudied.

Status of the knowledge of the biology of Dendroctonus valens:

In 1862 Harris (5) published the first notes on the biology of D. valens. Since then the general phases of the life history and the role of the species in forest economy have been well worked out by many investigators. Much is now known of the behavior of the species over the greater part of its extended natural range and under varying forest conditions. However, in spite of the great amount of attention the species has received during this long period of time, the intimate details of its biology remain to be followed. Questions on the length of development of the different life stages, the number of larval instars, the longevity, fecundity, and sex ratios of adults, viability of eggs, temperature relations, cold tolerance, and other biological characteristics offer opportunity for further investigation. By use of methods of artificial rearing these problems should be rather readily attacked and determined whenever a need for more complete biological data arises.

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